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# Lightweight Concrete: Innovations and Applications

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***Abstract:*** ***Lightweight concrete has become more and more popular in recent years, in the field of construction due to its aspects like cost effectiveness and design flexibility. The density of lightweight concrete is less than compared to the conventional concrete which reduces the weight of the structure while providing sufficient strength. With increase in the advances in the construction field, lightweight concrete is used in number of applications. The purpose of this paper is to study the properties, materials used, production method and various advances that have been recently adopted in lightweight concrete. With wide range of applications, it also has some limitations which we will discuss later in the paper. The paper describes the use of different materials like coconut shell, oil palm shell, pumice etc. in lightweight concrete and also discuss about the mechanical properties like compressive strength, split tensile strength, workability, flexural strength and durability of the light weight concrete. The development of recent advances has also been included in the paper. At last, the various challenges and need of future research are also discussed.***

***Keywords: Lightweight concrete, lightweight aggregate, fly ash, properties of LWC***

## I. INTRODUCTION

Concrete is the most commonly used construction materials across the world due to its high strength, versality and durability. But the use of conventional concrete is not feasible in the case where we need to reduce the weight of the structure. Here, the lightweight concrete has increasingly drawn attention due to its substantial benefits including reduce structural weight, thermal insulation and design flexibility. Typically confined to non- load bearing structures, recent advancement in high strength lightweight concrete (HSLWC) has increased its application in complex structures where high strength is required [1]. Lightweight concrete has been used from ancient times, traces can be found in Mohenjo-daro and Harapan civilization, moreover, it was also used by Romans [1],[2]. After the fall of Roman Empire, the use of lightweight concrete became limited due to the low availability of natural aggregates. Then the production of industrially produced lightweight aggregate was developed in the $19^{th}$ and $20^{th}$ centuries [3].

Lightweight concrete is a type of concrete that contains an increasing agent, which increases the volume of the mix while adding properties like reduction in the self-weight. Lightweight concrete can be produced by introducing: (a) gassing agents such as aluminum powder, (b) lightweight aggregates, (c) plastic granules as aggregate [4],[5]. In past, lightweight aggregates were made from natural sources like pumice but with development and scarcity of natural aggregates, some artificial chemicals were also started using in the production of lightweight aggregate. Usually, lightweight concrete is made from sintered fly ash, expanded clay & expanded shale [6],[7]. They contain large number of pores which in result lower the strength and leads to large deformability. Thus, the quality of aggregates used affect the strength of the concrete. Lightweight aggregates can be present in two forms: natural and artificial [8]. Lightweight concrete can be produced with an oven-dry density not greater than $2000kg/m^3$ [1],[9],[10].

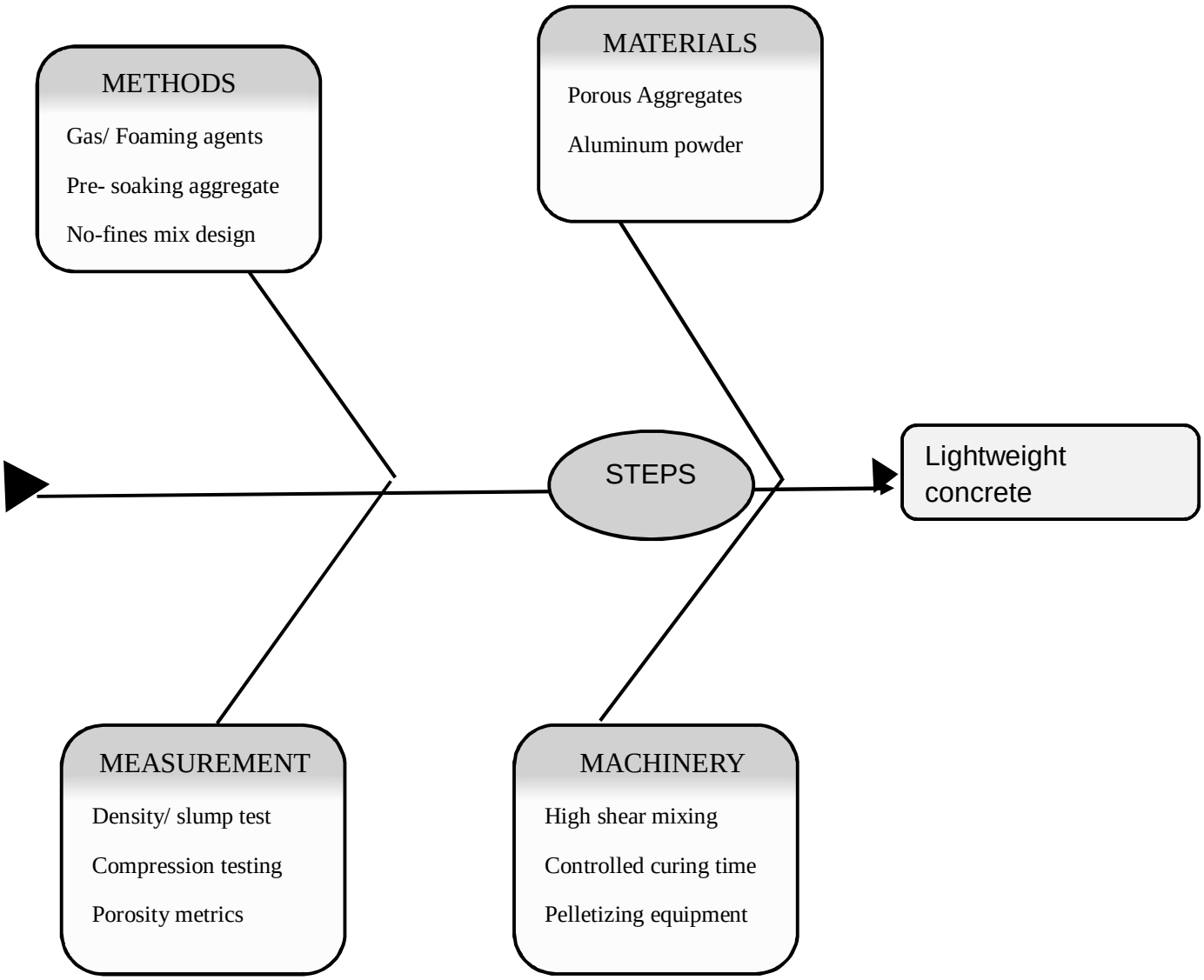
Researches on lightweight concrete showed the different properties which are beneficial to us and makes it more popular among the contractors and engineers. The one of the most important properties of lightweight concrete is the reduced weight of the mix. The use of lightweight offers various advantages like fire resistance, thermal insulation and low environmental impact. It is found that in case of fire lightweight concrete prevent the spreading of flames and cause less damage to the structure. Lightweight concrete has a good resistance towards freeze and thawing which make it suitable for many environmental conditions [11]. Studies showed that the mix containing 10% silica fume and 5% fly ash has better strength properties than the mix contain either silica fume or fly ash [8]. It is found that the compressive strength of LWC is mainly depends upon the quality of aggregates used [12]. However, the traditional LWC has low value of mechanical properties which makes it unsuitable for high-rise buildings. To solve this problem high strength lightweight concrete (HSLWC) has developed to provide high strength and better performance [13]. The applications of lightweight concrete are in the masonry, lightweight structure, pre-cast elements, geotechnical fill and road bases etc. which we discuss in the paper.

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*A. Objective*

- To study the use of lightweight concrete in our modern construction.
- To find the different materials used in the production of lightweight concrete.
- To understand the effect and use of fly ash, coconut shell in the production of lightweight concrete.
- To study the properties of lightweight concrete and their comparison with conventional concrete.
- To study the recent advances and various applications of lightweight concrete.




## II. OPERTIES OF LIGHTWEIGHT CONCRETE

*A. Density*

The dry density of lightweight concrete ranging from 300 – 2000 kg/m$^3$ which is low when compared to the density of conventional concrete [9]. The low-density lightweight concrete is produced using lightweight aggregates such as expanded clay, pumice, coconut shell or by introducing air voids in the mix. This reduction in the density helps in decreasing the dead load on the structure which make lightweight concrete suitable for high- rise buildings.

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Table 1: Typical Classification Of Lightweight Concrete

| Classification | Density Range | Typical Strength | Primary Use |
|---|---|---|---|
| Ultra-Lightweight | < 800 kg/m³ | 0.5–2 MPa | Thermal insulation only |
| Semi-Lightweight | 1440–1840 kg/m³ | 15–50 MPa | Structural slabs, beams |
| Lightweight | 800–1440 kg/m³ | 2–15 MPa | Partition walls, fill |
| Natural Weight Concrete | 2300–2500 kg/m³ | 20–60+ MPa | All structural use |

*B. Compressive Strength*

The compressive strength of lightweight concrete is mainly depend on the density of aggregate used, which is govern by the cement content [16]. It was found that on average for lightweight aggregate a 10% higher cement content will provide approximately 5% higher compressive strength [9]. Compressive strength value ranges from 45 to 65 MPa[18] Compressive strength of lightweight concrete can be increased by using admixtures. The compressive strength of LWC increases with time or age similar to conventional concrete [9],[15].

*C. Tensile Strength*

The tensile strength of lightweight concrete is found to be less than its compressive strength, generally flexural strength is 30% of compressive strength [9]. The introduction of fibers in the lightweight concrete mix will increase the tensile and flexural strength [17].

*D. Modulus of Elasticity*

From studies it was found that the value of modulus of elasticity of lightweight concrete increases as density and compressive strength increases. The experimental study on concrete with density 900 – 1100 kg/m$^3$ had modulus value of 3-8 GPa, on the other hand higher density mix 1300 – 1560 kg/m$^3$ contain modulus value of 16-24 GPa [19].

*E. Thermal Properties*

Thermal properties of lightweight concrete had low value than natural concrete. The coefficient of thermal conductivity for lightweight concrete found to be 0.22J/m$^2$s [9]. The microscopic air bubbles present inside the lightweight concrete can helps to reduce the penetration of heat which makes lightweight concrete resistant to fire. The freeze & thaw resistance of lightweight are high but can be reduced when the pores are saturated.

TABLE 2: Comparison between LWC and Normal Concrete Properties-

| Properties | LWC | Normal Concrete |
|---|---|---|
| Density | 800-1840 kg/m$^3$ | 2300-2500 kg/m$^3$ |
| Compressive strength | 15 – 50 MPa | 20 – 60 MPa |
| Modulus of Elasticity | 10 – 24 GPa | 22 – 30 GPa |
| Thermal Conductivity | 0.2 – 0.7 W/mK | 1.4 – 1.8 W/mK |
| Fire Resistance | Better (low conductivity) | Good |
| Shrinkage | Higher | Lower |
| Durability | Moderate | High |
| Sound Insulation | Good | Moderate |
| Dead Load Reduction | 25 – 50 % less | 0% |

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## III. LITERATURE REVIEW

Behera, Diptikar et al (2025) [1]: The paper reviewed that how lightweight concrete can be made from low strength materials into high performance and sustainable building materials. The paper also highlighted the use of supplementary cementitious materials, fibers, geopolymers, recycled materials which are recently developed to increase the performance of lightweight concrete. It summarized the various properties of lightweight concrete and found that the modern lightweight concrete can achieve high strength while the density remains reduced. The paper discussed the use of recycled materials, low carbon binders which helps to reduce the $CO_2$ emission. The future study on improving cost effectiveness, enhancing durability and long-term performance in different environment conditions of lightweight concrete were discussed in the paper.

Meena et al (2020) [2]: The paper examined the three-production method of lightweight concrete which are no fines concrete, aerated concrete and lightweight aggregate concrete. The paper reviewed the experimental studies using scoria, fly ash, volcanic pumice, fibers etc. and discussed their effects on properties of lightweight concrete. The paper concluded that the lightweight concrete helps in the reduction of structural dead load and enhances its thermal and sound insulation properties. Along with that it also studies the various advantages of LWC.

Thienel et al (2020) [3]: The paper reviewed the lightweight concrete from the very basic to the recent technological developments in LWC. It discussed the materials used in the production, production process, properties and the innovation of infra-lightweight concrete. The paper explained the density of European structural lightweight concrete generally ranges from 800 – 2000 kg/m$^3$. The author discussed the classification, application and limitations in the production of lightweight concrete. The development of infra-lightweight concrete has very low density (800kg/m$^3$) and high thermal insulating properties were discussed in the paper.

Ahmed et al (2025) [4]: The study discussed the different materials used in the production of lightweight concrete and their effects on the concrete properties. The main focused of the paper is to study the primary characteristics of lightweight concrete, such as decreased dead load and reduced density while obtaining a certain compressive strength. They found that the compressive strength of lightweight concrete ranges from 2.0 – 37 MPa, whereas when adding chemicals it can reached to 62 MPa. The paper discussed the effect of using polypropylene on lightweight concrete as the addition of 0.2% to 0.5% volume fraction of polypropylene fiber will reduce the slump and density and further addition of 0.7% to 1.0% will reduces the compressive strength of lightweight concrete.

Abdulkadir Kan et al (2009) [5]: The study investigates the effect of using recycled waste expanded polystyrene foam as an aggregate in the production of lightweight concrete. Modified waste expanded polystyrene aggregates were obtained by heat treatment method by keeping the waste polystyrene foams in a hot oven at 130$^o$ C for 15 minutes and their effect on the properties of lightweight concrete was investigated. For the experiment, six series of concrete samples were prepared and with the replacement of natural aggregate at 0%,25%, 50%, 75% and 100% by modified waste expanded polystyrene foams. The results found that MEPS has low density value and 28 days compressive strength ranges from 12.58 MPa to 33.34 MPa. The paper discussed the low density and high thermal insulation properties of lightweight aggregate prepared with MEPS but also stated the effect of porosity and water absorption property.

Nguyen et al. (2014) [6]: The paper experimentally investigated the influence of amount and nature of fine aggregates on mechanical and thermal properties of lightweight concrete on structural lightweight aggregates. In this paper seven types of LWA of three different natures were used- pumice, expanded clay and expanded shale and were tested to compare with the natural aggregate concrete. The results showed that the replacement of fine normal weight aggregate can reduce the density and improve the thermal properties but when the lightweight aggregate content is increased it leads to the reduction in the compressive strength of the lightweight concrete. From the experiment results, it was concluded that the mechanical and thermal behavior of LWC depends on the aggregate volume proportion but also on the aggregate nature and quality.

Yoon et al. (2015) [7]: In this paper the researchers investigated a two-stage casting process for producing lightweight concrete with a high volume of lightweight aggregates. It stated that minimizing density of lightweight concrete requires large volume of fraction, but causes segregation of aggregates in conventional mixing, thus they came up with an idea of two stage casting process. In this process they firstly placing the lightweight aggregates in the frame and

then filling the voids between them with cementitious grout. The results were found with the lowest density of lightweight concrete which consequently has low compressive strength value. It was also found that the irregular shaped aggregates contribute to the weaker points in the concrete while round shaped aggregates provide compressive strength of 20MPa. The proposed method was considered in the application where low density and moderate strength is required.

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Elango et al. (2021) [8]: This paper discussed the method of production of lightweight concrete and its properties like density, compressive strength, workability, durability, thermal properties, advantages, limitations and applications of lightweight concrete. The paper also discussed the use of various materials such as coconut shell, oil palm shell, vermiculite, Styrofoam, light expanded clay aggregate and variety of admixtures used in LWC and their effects on properties. The study showed the use of lightweight aggregates will help to reduce the density of lightweight concrete which make it suitable for high rise buildings and improved thermal properties. The paper recommended to select suitable lightweight aggregate and binding materials to achieve adequate strength.

Newman et al (2003) [9]: The paper discussed the fundamental properties of lightweight concrete and compare its properties with normal weight concrete. The author discussed the types and materials used in the production of lightweight concrete. The evaluates the influence of lightweight aggregate on density, workability, compressive strength, tensile strength, thermal conductivity and durability properties. The paper highlighted the characteristics of lightweight aggregates like porosity, workability and strength had a significant influence on the performance of lightweight concrete. The advantage of low density of lightweight aggregates helps to decrease the dead load of the structure. However, the paper also provides a vast range of application of lightweight concrete in the construction work.

Kumar et al (2019) [10]: The paper showed the use of vermiculite as a lightweight material in the production of lightweight concrete blocks. Vermiculite was collected from Andhra mines and due to its porous and lightweight structures were used in the preparation of lightweight concrete blocks. Cube moulds of 150 X150X150 mm were casted and tested. The experimental results of compressive strength at 7, 14 and 25 days give reliable results with Indian standards and the density results found out to be average dry density of block as1866 kg/m$^3$, 1943 kg/m$^3$ and 2010 kg/m$^3$. The results indicated that vermiculite lightweight blocks can be used in the construction industry for reducing the self-weight of the structure. The results also showed that the blocks can be used for load bearing structures and the use of locally available lightweight materials helps to reduce cost of the structure and are environment friend.

## IV. APPLICATIONS OF LIGHTWEIGHT CONCRETE

*1)* Lightweight concrete is used in high rise buildings due to the reduction in the dead load of the structure. The lower self-weight of structure helps in the reduction in size of structural members and foundation and improve the overall structural efficiency [13].
*2)* Lightweight concrete is also used in bridge deck and other bridge components due to its reduced weight which in result increase the span length and load carrying capacity.
*3)* Infra-lightweight concrete can be used in load bearing facades which provides good thermal
*4)* insulation, low density and adequate strength [21].
*5)* Lightweight concrete can also be used as floor slabs to reduce the dead loads of the structure.
*6)* Lightweight concrete is mainly used where thermal insulation is required because it has porous structure due to which has very low value of thermal conductivity [3],[21].
*7)* Lightweight concrete provides good thermal and fire resistance than conventional concrete making it more suitable for fire performance.
*8)* Due to the reduction in the self-weight of structure made from lightweight concrete it is beneficial in the earthquake prone regions to make seismic resistance structures.
*9)* Lightweight concrete is used in the production of precast and prefabricated components because of its light weight which makes the handling and transportation easier.
*10)* High-strength lightweight concrete can be used in the marine structures where high strength and reduce structural weight is important.
*11)* Lightweight concrete is used in the production of many structural components with high strength and reduced density.

## V. RECENT ADVANCES IN LIGHTWEIGHT CONCRETE

Recent developments in the lightweight concrete mainly focused on improving strength, durability, suitability, performance and reducing density. The use of pumice, vermiculite, expanded clay, crushed clay brick and coconut shell in concrete mix can helps to decrease the density of concrete. Tsioulou et al (2025) highlighted the use of aerogel powder and beads in production of high strength lightweight concrete which helps to increase the thermal properties of lightweight concrete. Aerogel improves the thermal insulation of concrete due to its very low thermal conductivity.

The development of high strength lightweight concrete with the use of high-quality lightweight aggregates, supplementary cementitious materials, geopolymers, fiber reinforcement will help to enhance the performance and sustainability of lightweight concrete. The development in the production of lightweight concrete from recycled materials and industrial by-products also improves the properties of concrete.

## VI. FUTURE SCOPE

From studies we found that lightweight concrete is mainly used to reduce the dead load of the structure and improving thermal insulation. Lightweight concrete has many advantages but further research is required to develop high strength lightweight concrete while maintaining its low density, improving its long term-performance, optimization of mix design, use of sustainable materials and reduce cost of production.

## VII. CONCLUSION

Lightweight concrete has been widely used in the construction due its low density which leads to reduced self-weight of the structure and for improved thermal properties. From the above studies we will come up with the following conclusion:

*1)* The quality and proportion of lightweight aggregates can significantly affect the physical and mechanical properties of lightweight concrete.
*2)* Use of supplementary cementitious materials like fly ash, silica fume, expanded clay, pumice etc. will helps in improving properties of lightweight concrete.
*3)* Partial replacement of aggregate with coconut shell will helps to reduce density and increases the strength of lightweight concrete.
*4)* The innovation of two-stage casting process and use of minerals such as vermiculite helps in the improving the performance of lightweight concrete.
*5)* Lightweight concrete is widely used in high-rise buildings due to its low density which in result leads to reduction in self-weight of the structure.
*6)* The development of infra-lightweight concrete for providing low density, good thermal insulation and adequate strength.
*7)* However, some challenges can be seen related to the water absorption, reduce strength and high production cost.
*8)* Thus, future research will be required to overcome these challenges to obtain a cost effective and environmentally sustainable lightweight concrete.

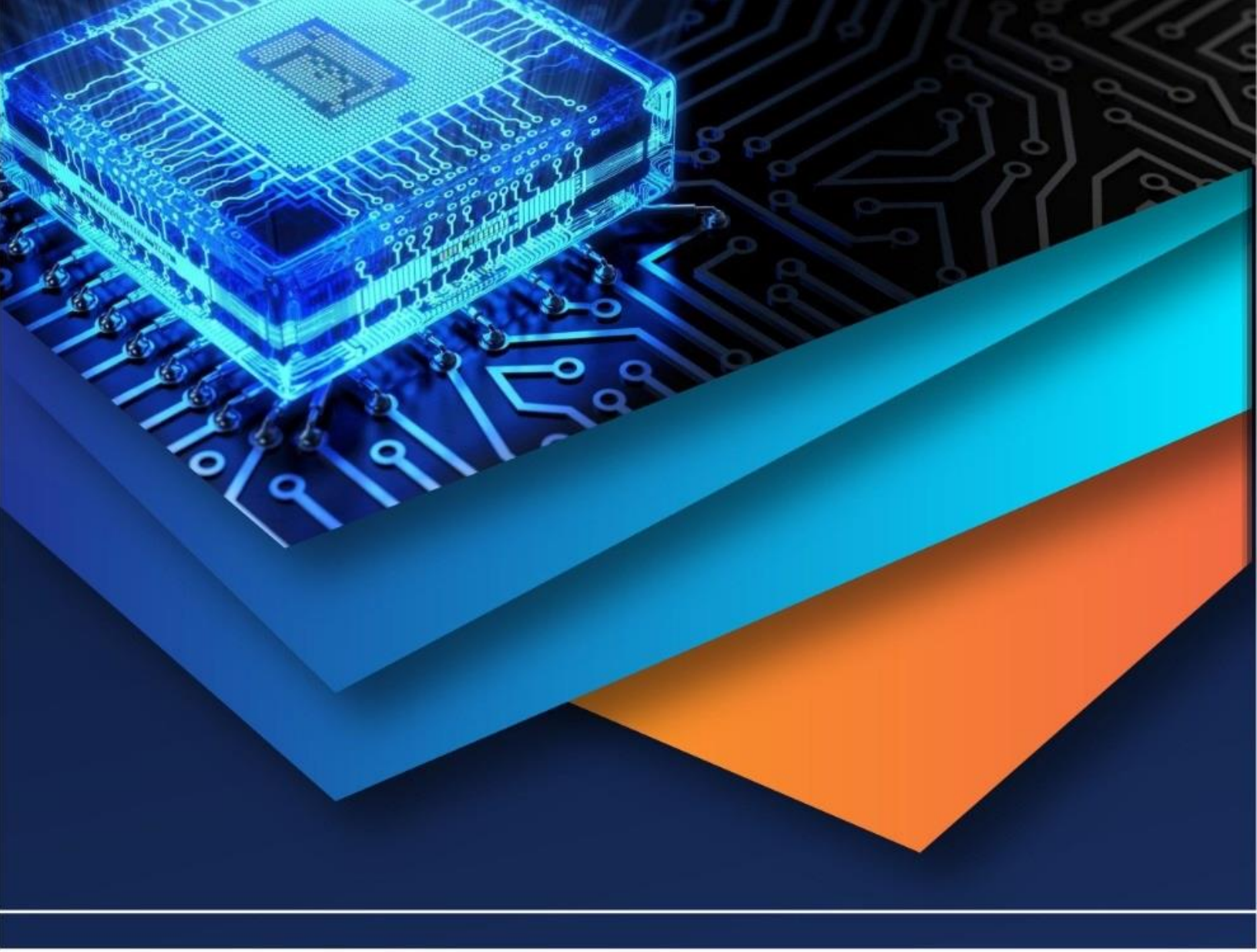
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